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ABSTRACT

This is one in a series of eight discussion pamphlets produced by the Writing Across the Curriculum Project dealing with some of the issues connected with writing in the schools and their relation to learning. The seven papers in this pamphlet were drawn from a seminar involving a small number of science teachers and cover a variety of topics, including science as a process rather than a body of knowledge, the contribution of writing tasks to a child's scientific understanding, provision of a range of audiences in science writing, and the implications for language development of the sorts of tasks being set on science worksheets. (FL)

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WRITING IN SCIENCE

Papers from a Seminar with Science Teachers

The Schools Council and London University Institute of Education Joint Project
Writing Across the Curriculum 11-13 Years

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WRITING IN SCIENCE

Papers from a seminar with science teachers

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HOW THIS PAMPHLET CAME TO BE WRITTEN

The *Writing across the Curriculum* Project is funded for a limited period (i) to disseminate the findings of the Schools Council five-year enquiry into *The Development of Writing Abilities, 11-18*, and (ii) to work with teachers of all subjects in examining ways in which the pupil's writing may more effectively contribute to his learning in all subjects of the curriculum and to his personal development. Teachers are attempting to relate the general ideas of the Project to the problems and strengths of pupils within their own school and are also trying to solve some of the language problems common to all disciplines. Initially our brief was to concern ourselves with writing within the 11-13 age range but the second phase of our work is to focus on the 13-16 range.

At the beginning of May 1974 the Project Team held a seminar for science teachers at Wansfell College in Essex. We invited teachers whom we had already met through our work in schools to join us for a weekend to consider the use of writing in science teaching and learning. In the event seven science teachers were able to come, and also the Head of King Harold School at Waltham Abbey. We were fortunate in having with us biology, chemistry and physics specialists, all of whom were also involved in running combined science courses for the 11-13 age groups– and in some cases up to 'O' level.

We had asked those participating to bring samples of writing in science from their schools and these, together with some of the data and findings from the previous research project, *The Development of Writing Abilities, 11-18*, gave us common reference points for our discussion.

Because, for two and a half years, we have been chiefly concerned with the 11-13 age group, the majority of the writing samples quoted here lie within this range. Nevertheless, several of

the papers in this pamphlet do in fact cast forward in their arguments.

After two sessions together in which we raised and discussed broad issues about the purposes of writing and the extent to which it was related to thinking–and more specifically its value in learning science–we divided into three working groups to explore the following questions in more detail and, if there were to be sufficient agreement, we planned also to write the first draft of this pamphlet.

Group A
(i) What value has children's own informal, near-to-speech writing in helping them to understand scientific concepts?
(ii) How can they be helped to become familiar with the modes of language in which scientific and technical information is presented to a wide public audience, and to be able, on occasion, to use it themselves?

Group B
What opportunities for learning can worksheets offer, and how does the way teachers use written language in their worksheets affect the response of their pupils?

Group C
How can writing opportunities be widened in science by varying (i) the audiences for whom the children write and (ii) the purposes of the writing?

Broadly speaking, this pamphlet falls into three sections which reflect the work of the three groups. The illustrations are almost entirely drawn from the written work that members of the seminar brought with them; and, by the Sunday evening, much of what we had covered together in discussion was in rough draft. People wrote in various ways. Some preferred to contribute individual papers; and, except for the editing of overlap, these are as they came to us. Others discussed their topic, and made agreed notes on what should go into the papers. Their notes were subsequently written up by members of the Project Team and sent to participants to amend. We hope that the thread of our general

concern as to how writing can help learning in science is sufficient to hold the various contributions together.

This was the first intensive workshop with interested teachers from a single school subject that our Project had organised. The discussion of the implications of the Writing Research findings, together with consistent reference to actual work in schools, generated a sense of opportunities opening out. We hope that some of these possibilities will be communicated in the papers in the pamphlet, but we know that the most significant insights occurred—as might be expected—in the talk: when (necessarily) transformed into explicit transactional writing, the excitement, or concern, demonstrated in the spoken utterances has largely disappeared. We have decided therefore to begin with some contributions to the discussions that took place in the first two sessions. They are presented disconnectedly.

ITEMS FROM THE OPENING DISCUSSION

- Two considerations that face science teachers:
  1) the child's own language and where he is;
  2) the body of scientific knowledge that you want the child to learn.
- What do kids see experiments as being for? 'Is it a real problem for me to solve?' or 'What does the teacher want me to do?'
- Genuine science outside school is about solving real problems.
- There are difficulties sometimes about using real situations first—when the apparatus found in a real situation is often so complicated—where artificial situations can be so much simpler . . .
- There are dangers of the teacher-as-expert inevitably putting the child in a situation which only makes sense when you know beforehand what you're trying to do. We don't provide children with the situation where *their* processes, not ours, structure what they do.
- Worksheets look easy to the teacher, but for the kids there is a lot of thinking to be done—and discussion.
- We tend to use writing unthinkingly—i.e. in a very structured

way: 'What to do', then 'What to write'. We break writing tasks down into a number of questions to which fairly short replies are required. There is very little opportunity for open-ended writing.

I try to arrange every piece of worksheet work so that it begins with a few general questions introducing the idea and ends up with writing which brings in the children themselves. This will depend on the actual subject matter of course.

We felt strongly that a mixed ability situation would demand that the teachers' worksheets must be understandable to all the children with the main view in mind, 'Will he be able to get the answer we want him to get?', because if not it's going to be awkward for going on to the next piece of work.

1. THE DEVELOPMENT OF WRITING ABILITIES, 11-18: Findings from the Five-Year Research

by Harold Smith

The Schools Council Project: *The Development of Writing Abilities, 11-18* was interested, as a first stage in its enquiry, in how writing was used in schools. The team therefore collected samples of writings from all subjects of the secondary curriculum which used continuous writing, and from all types of secondary school, in various parts of the country.

A multi-dimensional and descriptive model was developed to describe the writings; the two axes furthest developed being those of 'function' (*what* the writing was for) and 'sense of audience' (*who* it was for—or, more specifically, who was in the writer's mind and influencing his writing whilst he wrote).

The major sub-divisions within 'function' were into Transactional, Expressive and Poetic writing. These three functions were conceived of as lying along a continuum, so a piece of writing may have been classified as lying, for instance, somewhere between the transactional and the expressive uses of language.

In the transactional category we find language in which the writer is engaged in a task, such as recording, reporting, classifying, persuading, hypothesising, speculating, theorising. In the poetic category his concentration is on making something, on constructing a whole and concentrating on making, in language, something which is the outcome of his personal vision and which his reader is expected to take as a whole rather than merely the sum of its parts.

Expressive language is close to that of talk, often loosely structured and context-bound; it makes the assumption of a common interest between writer and reader—and an interest in the writer as a person as well as in his subject matter.

Expressive language was looked upon as a sort of matrix out of which the more specialised functions could grow. It is the language typically associated with young children, but it is also the language often used by adults when first grappling with new ideas—a language of the early stages of assimilation.

It seemed that expressive language had an important role to play in learning; that, ideally, it would offer the opportunity to a pupil to make sense of ideas and information in his own terms, that it would also allow him to relate the new to his existing picture of 'how things are', to relate his outside experience to that of the classroom—in total, allow him to undergo the processes which Piaget called 'assimilation' and 'accommodation'.*

It may be that much of what expressive writing may have to offer is gained equally through the talk that goes on during experimentation, but the actual writings in the research survey gave a strong impression that assimilation was not complete; that the pupils had been asked to write their final thoughts on the subject before those thoughts were finalised—and to write in *someone else's language.*

Even if assimilation were taking place to some extent through talk, writing has, by its very nature, a number of things to offer which talk could not have: time for reflection, freedom from interruption, the possibility of holding ideas together for long enough to see the links, to forge new understandings.

So, it appeared that expressive language had much to offer the learner, but nevertheless it was little used in the schools in our sample. Only 5% of the writings from all subjects fell into this category; even 11 year olds, just entering secondary schools, only used the expressive in 6% of their school writing. In science

* Piaget J, *Play, Dreams and Imitation in Childhood*, Heinemann 1951

lessons no evidence was found of expressive writing being used at all.

By far the greatest bulk of the writing in all subjects was transactional–and of that the vast majority was to give information, either in the form of report or in generalisation; and in science all the writing was transactional–again nearly all reporting or generalising. The absence of speculation and hypothesis in the pupils' writing, even amongst sixth-formers, was noticeable. (The strong impression was gained that the unbroken 'diet' of transactional writing had led the pupils to believe that their own thinking 'didn't count'–that what was required of them was the regurgitation of someone else's thinking in someone else's language. That could well explain the absence of speculation and hypothesis.

When the writings were examined for 'Sense of Audience' it was found, as would be expected, that most of the writers had a teacher audience firmly in mind. But, on examining these scripts more closely, it became clear that very often it was a particular sort of teacher that the writer was considering–a teacher seen in the role of examiner.

The following table shows the incidence of that particular audience:

Subject	*Percentage of All Scripts in 'Teacher Seen as Examiner' Category*
English	18
History	69
Geography	81
R.E.	22
Science	87
All subjects	53

The overall impression of secondary school writing, then, was of its being used to convey information in a test situation–informing the already informed.

It is in the belief that writing could do more for pupils than

this that the Project Team of *Writing across the Curriculum* has been working with teachers to find ways in which the writing process could more effectively be used. How writing may more effectively be used in the learning of science is the basis of this weekend's discussion.

2. SCIENCE AS A PROCESS: A CHANGE IN EMPHASIS

by George Goldby

There seem to be two different and conflicting goals in science education: one is to teach a body of accepted knowledge, the other is to teach the process by which that knowledge has been discovered. Of these two goals, the former continues to be dominant in science teaching today, but I believe that the latter goal—the process of science—is by far the more important. The way we work is bound up with the way we use language, and a change in emphasis from science as knowledge to science as a process would require, amongst other things, a change in the way we use language in science education.

Teaching science as an agreed body of knowledge requires from the student a passive and accepting attitude; teaching science as a process of investigation and problem solving requires exploration and self-expression. When science is taught as knowledge, the students are drawn towards a static, predetermined end; but when science is taught as a process, the end is neither fixed nor predictable: it is instead the process of the investigation, and the outcome of this process is essentially uncertain.

The part played by writing in science education reflects the choice of goal. If, in the end, the lesson is directed towards static, impersonal knowledge, then transactional, informational writing will be the appropriate method of expression and communication. The dominant part that this informational writing still plays in the science work of school-children shows how far we avoid the development of scientific skill or method. Science teachers reveal by what they ask the students to write that they see little room for self-expression and exploration in the kind of activity which they provide.

However, science is primarily a process of personal observation and investigation. If, as seems likely, work needs to be developed and communicated by language which is appropriate to the character of the work, then the observing, thinking and investigating in science should initially be articulated not through transactional but through expressive writing which–like the work–is both personal and exploratory.

The suitability of expressive writing in science is illustrated by the example of observing a burning candle (quoted on p.15 below) below). Through expressive writing, this student has been able to develop and express her own undirected observations. As a result, she has identified specific problems (such as 'How does the wax climb up the wick?') which could form the subject of more extensive investigation. Another example of the use of expressive writing in the early stages of science work is provided by David's piece on 'Air'. Through writing this story, the student has the chance to establish firmly that the air around him, although invisible, has substance and is real. Furthermore, the evidence which children give to support the idea that air is real (air helps burning, air makes bubbles in water, air can inflate balloons) provides the starting points for major investigations (the composition of air, its physical properties, the relation between pressure and volume of gases, for example).

DAVID

Context:

First-year science: discussion about air–how do we know it is real–that there is anything there? The children were asked to write a story about a boy who goes out into the world to try to prove the reality of air.

The Search for Air

I am henry Kenyon of Middleton and I am very interested in science. For years now I have had a problem. How can I prove air is there? My mum has told me that air is around us but I can not have any proof. I pursuaded my mum and dad to let my uncle henry help me solve my problem. My first journey was to holland where all the tulips and windmills are (and also cheese, but I don't like it). I started walking inland and looked round for some evidence, but I didn't see any

until one hour later. Then I saw it, a windmill! There must be air in the wind and I could see there was wind because the sails were going round and they are propelled by wind. But this was not enough. I then went into ice-land where it is very, very cold. I put on loads of clothes and walked out. WOW! What a wind there was. But this was my final evidence. I already have explained about air being in wind but now I could see bits of snow flying in the wind. Now my problem was finished.

The End

I thought I was finished but my teacher said I had to do some more. I got a glass of milk and a straw. then I blew down the straw into the milk and bubbles came up. And this is another piece of evidence because as you know bubbles are round. In the middle of the bubble there must be air because air is supporting the skin of the bubble.

Teacher's comment:

I think I was quite wrong to ask him to do more. His story was a complete story.

Another comment:

Since his story was regarded as inadequate he abandons the 'game' of story-telling and dives straight into the science mode of report plus explanation.

Expressive writing seems suited not only to the early stages of an investigation, but also to that part of the process when observations and experimental results are for the first time being drawn together and connections are being made. A poem inspired by a course on human reproduction I think illustrates this point, thoug though in this case the observations and results of investigation were inevitably acquired second hand:

ADAM

The Unborn Child

Zygote to the embryo it really really grows
Whether its a boy or girl no one really knows,
Inside the mother's womb wonders still untold,
What are we really like, three weeks old?
Inside the sack of clear fluid everything is still
He does not have to run from animals that want to kill.

His blood in his veins is his only support
What will he do when he is born out of his fort?
The little baby has no thoughts inside his head
But he doesn't really need them on his comfy little bed.
When he gets older he will reproduce a baby of his own.
And there will be another embryo with a brother, or alone.

Only in the last stage of science work, when the outcome is being communicated in a final and unambiguous form, meaningful to a wide audience, does transactional writing need to take a dominant role. The use of this more formal writing at the end of a piece of work is shown in the summary of results of a study of fingerprints (quoted on p.29):

1. All together there are seventy-six loops out of one-hundred and forty. That is 53%.
2. The least commonest is composite which only has three prints out of one-hundred and forty. Which is 2%.

This example seems to reveal a sense in the student that the end of a piece of work should make a formal communication that is conclusive, unambiguous and meaningful to a wide audience.

If science is important as a problem-solving process as well as a body of knowledge, then the present emphasis of science teaching should change, and expressive writing–amongst other things–should play a larger part than it has done so far. Expressive writing is important because it is a form of language appropriate to the process of problem-solving, and because writing in this way helps the students, as they pursue their work, to form and develop their own rather than their teacher's ideas.

A change in emphasis from science as knowledge to science as a process would involve more than a change in the use of language. For most of the time, teachers still impose on their students–by talk, blackboard, study guide or worksheet–structures which, in effect, tell the student what questions to ask, how to answer them, and what the answers ought to be. Teaching science as a process would require open ended situations where the choice of questions and the choices involved in

the search for answers are genuinely in the hands of the student. A combination of such real investigation and expressive writing could become an important step forward in science education.

3. SCIENCE:
Writing & Understanding-
Writing & Learning by Sue Watts

Much of the material we deal with in science is ideas; we hope that the children will develop their own ideas about the world around them. These ideas can be backed up by the evidence of their own experimental investigations and by reference to previously learned skills and facts.

Expressive language is important if we take this view of science teaching because it is closely related to thought and ideas. When a group of children is presented with a problem, many ideas, explanations, answers, suggestions for experimental work etc. arise. While experimental work is in progress children (and teacher) may talk about what is happening or what they are doing, many ideas may be thrown in, some only to be discarded almost immediately. On the whole I find children unwilling to put these ideas on paper, they do not wish a permanent record to exist. They may write a few notes for their own personal use. When they are a little more satisfied with their own ideas they may try writing as a way of sorting these out. This is illustrated by the example of writing from a group of first-formers who had been doing work on what happens to copper when it is heated (pp.19/20).

Writing done while an experiment is in progress or while observations are being made tends to be very personal; it's often a list, or set of information the child may use later. 'Writing-up' after experiments is often still very expressive, children are not always certain of their ideas. The work on the candle done by a group of first year girls illustrates the different ways in which the children decided to write about what they had done. Vicki wrote her list as she worked and left the lab. telling the others how

much she had found out. Anna spent time later writing about what she had done and seen. She seems to have felt the need for a word ('technical term') to describe how the wax gets up to the flame–'. . . sort of climbs up . . .' Michelle also uses her own ideas and, although some of her writing is not as clear as the other two examples, she has reached a stage further, she is able to generalise from her observations.

VICKI

Watching a candle burn: things I have noticed about a candle

1. It gives light.
2. If the flame is kept still it will stand up straight.
3. It gives a flame like the bunsen burner with the air hole closed but the flame on the candle is more still.
4. It has four different colours in the flame. Blue at the bottom on the wick, dark orange above the blue, yellow in the middle with a faint orange line going through the yellow, then at the top it goes orange.
5. The wax gets to the flame because the wick soaks up the wax, so if you light it, you will get a flame.
6. At the top there is a wax liquid.
7. Some of the wax has turned into a gas.
8. When you blow out a candle it gives out smoke and a burning smell.
9. When it burns wax pours down the side and goes hard.
10. As the wick burns it turns into a black cord.
11. At the end of the wick it is orange.
12. As you flick your finger through the flame, it doesn't hurt but you can feel warmth.
13. If you put a lighted spill just over the wick on the flames, it should light. This is because some of the wax turns into a gas and it escapes so if you lit it it would come alight.
14. When I put a glass vase over the flame it went out, but if I brought it up in time the flame would have stayed alight. It goes out because no oxygen could get to the flame.

ANNA

The Candle

As I look at the candle I see that the very bottom of the flame is blue then as you look higher up you can see a brownish yellow then higher

up it is a bright yellow, then when you look at the very tip of the flame it is a brownish yellow again.
If you hold your hand quite a way up from the flame, you can still feel the heat quite strongly, strong enough to make your hand sting.
If there is someone walking by the candle will flicker, also if you are breathing quite close to it.
Even though the flame does not touch the wax the wax burns away. I think it is that the wax sort of climbs up the wick so it will burn the wax.
When the wax burns it does not only turn into a liquid but also into a gas. We lit a spill, then blew the candle out and put the lighted spill quite a way over the wick, then the candle lit.
We also put a tall jar over the candle and saw the flame go out as the candle had burnt up all the oxygen what a candle needs to burn.

MICHELLE

A Candle when it burns

My candle is on a slant with a black wick and white wax. The bottom and the top of the flame is orangy gold the middle is a yellowy gold.
As the wick burns the wax turns to a kind of oil liquid. The liquid runs down the candle and drys to more wax.
When you blow it it flickers and that's the only time you can see smoke go up.
Outside the flame there is a kind of blue which outlines the flame from the middle of the flame to the bottom.
The wax reaches the wick by soaking up to it as paper soaks into water.
The wax when it turns to liquid it also turns to gas because when we blow the candle out all we have to do is light the liquid and a flame appears on the wick.
A candle needs air to keep it alight so if you blot out the air around it it will go out as soon as you do blot out the air, at least my one did.

I think these examples show part of a spectrum of the ways in which children write, from the straightforward list of observations to the start of generalisation and speculation. All these types of writing are important; the child begins with the observations, thinks about them and then, we hope, begins to generalise.

I feel (though as yet I have no evidence) that these are steps towards good transactional writing. I would hope that from these

beginnings we would later see the child being able to sort out which is the strictly scientific content of the work and which the personal details.

We need to provide a wide range of opportunities so that there will arise different types of writing, giving pupils as much chance as possible to write. Rosemary Sherrington's stories about William Harvey (quoted on pp.24/5 below) illustrate how a different type of writing has been used; the children have still used some scientific concepts.

One of the most important aspects of science, which is often neglected in school science, is the creative. If we are hoping to encourage children to think about their science we must give them as many opportunities as possible of different ways of thinking and looking at their ideas. How many important scientific discoveries began with a 'lucky accident'? The 'lucky accident' alone is not sufficient, the scientist involved had to think up new ideas to go with the chance observation.

I feel that there is a great danger in the constant use of worksheets in science teaching. These, surely, take most of the ideas and creativity out of the child's approach to science. The automatic response of the child in school faced with a well-structured set of questions on a worksheet is to work through these, attempting simply to get the 'right answer' to each part and not thinking about anything more than is asked of him in a particular question. This will be especially so with the type of worksheet where spaces are left and answers of one or two words or a phrase are required.

Even without using a worksheet we can impose a structure of our own on the pupils. This could exclude their own ideas if we're not careful. The pupils in one of my first-form groups were heating substances to see what happened to them. I suggested that they wrote their observations in the form of a table and didn't ask them to write anything else (they know that I would read anything else if they did write more). Anna wrote her results as I suggested, it's simply a record of her observations. In addition to this she had done a piece of much more expressive

writing in which she told me exactly what she liked and thought important.

I would hope that the use of expressive writing will help the children to understand and develop ideas in their science lessons. Once they understand what they're doing they will realise which parts of what they have done are 'scientifically relevant'. When the children understand this they will be able to write at higher levels of transactional writing. I would also hope that by more personal involvement in their science they will find it more interesting and exciting and thus, eventually, easier to learn.

ANNA

Last weeks	This weeks	Things that stay the same	Things that go entirely different
Copper	Zinc oxide	*Red lead* changes when heated but when cool turns back to before it was heated.	*Copper* because goes black
Copper carbonate	Ammonium dichromate	*Zinc oxide* changes colour when heated but when cool turns back to before it was heated	*Copper carbonate* changes to a black powder
Magnesium	Red lead	*Lead metal* changes into a liquid when heated but when cool turnes back to a solid	*Magnesium* flares up and then drops off
Ammonium chloride	Iodine		*Ammonium chloride* makes a white vapour
Cobalt chloride	Lead metal		*Cobalt chloride* changes colour
Copper sulphate			*Copper sulphate* turns white and stays white
			Ammonium dichromate turns to a greeny black and bubbles and sparks
			Iodine turns mauve and is a vapour. Vapour then disappears and glitter is left in the tube.

SOME FURTHER WORK FROM ANNA

Heating Substances

a) Today we did an experiment where we heated substances. We had a lot of funny results like the Magnesium. When we put that in the flame of the bunsen burner it flared up bright for about six seconds and then dies down. It was a metal when we put it into the flame but after it flares up it is just bits of white on the asbestos sheet. There were two other funny ones, they were Ammonium chloride (which I got in my cut) and copper. The copper one was a bit of copper in a test tube that had to be heated. (Amanda left the tube in the flame to long so the tube began to melt). The copper went black. When it was nearly cool the black stuff began to peel itself off. Underneath there was just a bright orange/red colour. The Ammonium chloride was a white powder in a test tube. When it was heated it made a white vapour up the top of tube. When it was cool the white marks were still on the test tube. We did some other experiments like, Copper carbonate, Cobalt chloride and copper sulphate. These results were not as good so I won't tell you about them.

b) Today we did some experiments following on with last weeks. There were some good ones this week one was Iodine. There was only a tiny bit of it in the test tube. When it was heated it made a deep mauve vapour up the tube with a glitter on the sides of the test tube. When it was cool the deep mauve vapour disappears and only the glitter was left. Another good one was Ammonium Dichromate. It started of as orange granules. But when heated it sparked, bubbled and began to blow out of the tube. The powder began to turn a greeny black powder. When it was cool it stayed a greeny black powder. I think the best one today was lead metal. It was a bit stronger than foil but was a deep grey and very bendy. It was not heated in a test tube but a broken evaporating dish. Miss Watts put the lead metal on to the dish and held the dish in a pair of metal tongs. The metal began to melt. It changed from colour to colour. Some of the colours were purple, red, orange, yellow, blue and green. Then Miss Watts tipped some of the liquid onto the asbestos sheet. It then turned back into a solid but different shapes. There were some other things that we done today but they they were not as good. Here is a piece of the metal. [Metal attached.]

c) Copper

Today we did an experiment finding which was the substance that was making copper turn black.

We had a small piece of copper and we had to fold it up a certain way so that the air would not get in. Then we got a hammer and hammered

it down tightly to make sure no air would get in. Then we got a pair of metal tong's and held the copper over a bunsen burner. After a while it began to turn black. Then we put it down on the asbestos sheet and waited for it to cool down so we could undo it.
When it cooled down we undone it and were quite amazed as it was a copper colour.
I think that it is something in the air around the copper that gets burnt and then cling's, so that is why it goes black.
Here is the copper. [Diagram]

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4. SAMPLES AND COMMENTS

by Rosemary Sherrington

This paper consists of some of the admittedly disconnected samples of writing in science which we examined during the weekend, together with my initial reactions to them.

1. EXPRESSIVE LANGUAGE

> Expressive language helps the process of thinking.
> First drafts of uttered thinking are likely to be in expressive language.
> (From the Project Team's introduction to the discussion)

If true, these statements have great importar ce in science teaching.

(A) JAYNE (1st year)

> Rock Salt
>
> thirst of all Sharon and I got a tripiod a bunson burner a big beaker and a conical beaker and some filter paper and salt. What we done was tipped some salt in to a little dish thing and bashed it up with a pestle and mortar and then when it was thin we tipped it in the conical flask and then we put it on the bunson burner and waited. it took about 7 minutes and when we switched the bunson off it looked like real good salt.

This certainly tells us about Jayne but it is expressive writing trying to fill a transactional role. It is inexplicit and therefore not efficient. Jayne is not involved in her writing but she knows what she got was 'good salt'.

(B) NIGEL (5th year)

> C.S.E. topic on getting alcohol from newspaper
>
> (He was not asked to present his project in any given way. This is the last sheet of his project.)
>
> My project worked very well and I'm pleased because i) I got alcohol from paper which I thorught was never possible, ii) because I used

some new aquipment which I've never herd of let alone worked with.. Another thing I was pleased about was there was lots of experments and if there was anything I wanted to know there was book's at my finger tips so there wern't any time lost. If I had a lot more time what I would like to make is a lot more alcohol and do lots of flame tests because I only made about 1cm^3 of pure alcohol. So I could not do much, I would allso like to find how much yeast is necessary to ferment it propley yet let the alcohol burn propley. I would also like to know if it was the yeast that stopped it burning. I would also like to learn how to control the heat when distilling because that a mistake I made.

Teacher's comments:

His style contrasts with the other project accounts which were mainly written up in a formal way and without the ideas for further work included here.

His enthusiasm and pleasure derived from the project are refreshing, but more important throughout there is evidence of clear scientific thinking in Nigel's own words.

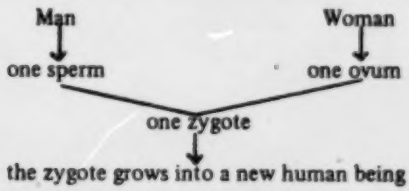
This boy is involved and evaluates what he has done. He asks fresh questions and sees his work as an ongoing process.

(C) IAN AND ADAM (1st year)

Two responses to the study of human reproduction showing marked contrasts in the use of language

i) The way the class booklet expresses it

Topic 1 – The Zygote: the start of a new life.



Topic 2 – The zygote grows.

ii) The way Ian expresses it: answers to questions on sheet

Topic 1 – When a woman is pregnant it means the embryo is growing.

– The embryo would be able to keep alive from the mother's food.
– The embryo would not have the same protection as in the womb.
– The disadvantages might be that if the mother got a really hard bang on her stomach the baby might die.

Topic 2 – It takes the embryo nine months to grow into a baby.
– I suggest that the baby gets its food and oxygen from the cord attached to him.
– The watery sack of fluid is probably used for protection.

Homework

1. No its not a good idea for a woman to smoke and drink heavily because if the mother is unhealthy while she is pregnant the baby might be affacted.
2. The doctors have to be careful about the medicines they give the mother, in case they give a medicine that gives some side effect that could harm the baby.
3. When the mothers were given this drug it made them sleep but when the babies were born they were deformed in different ways.

iii) Adam's poem

Adam's poem 'The Unborn Child' (quoted on pp.11/2) arose from the same work. It was a voluntary offering.

The science lesson where Ian learned about embryo development demanded very little in the way of writing.

An English lesson produced Adam's poem. I would argue that there is a need for a child to express himself in this way. Further, that this process has distilled his thinking and shows how magnificently the concept of the womb's protection has developed to produce the fort image.

By being allowed to write expressively Nigel and Adam have been able to evaluate their work and seem to have developed in two ways–in their critical faculties and in their concept of 'science'.

It is necessary to convince children of the value of expressive

writing. A sense of what sort of thing they should write is very powerfully built up in school, largely unconsciously. The expectation in science is usually for short sentence or phrase answers to exam-type questions, which are then considered as final, finished products. There are ways of breaking this expectation.

2. AN HISTORICAL APPROACH

An historical approach can provide dramatic examples of how scientific discoveries were made and how scientific thinking developed.

The teacher in this case wanted some imaginative writing and told the children about a picture she had seen as a child. It was of William Harvey kneeling at Charles II's feet with a bloodstained handkerchief in his hand. The contrast between the immaculate king and his court and the short, drably-dressed man with blood on his handkerchief had fired the imagination of the teacher. It did not inspire the children in exactly the same way of course, but their writing shows differences in imaginative approach and in expressiveness of the writing.

Gary assumes a common knowledge (of Harvey's medical discovery) with the teacher. He does not mention what Harvey found but reflects his own imaginative interest in the dramatic enactment of the supply of bodies. Jeanette's piece, on the other hand, although still highly expressive, explores the wider implications of scientific argument and 'proof' and ends with a global generalisation well on the way to a higher level of transactional writing.

(A) GARY

Finding is believing

One dark night a barrow stopped outside William Harvey's home. Two men got out and they went round to the back of the barrow and got a body out, and took it in the house. William Harvey said 'put the body on the table'. The body was of a murderer. He had been hung, and William Harvey got stuck in. He cut the man open and he found out

that his believing was right.

(B) JEANETTE

William Harvey

William Harvey was working late one night. He was getting the notes ready for the next day as he was giving a lecture to some doctors. He was writing down the things he would have to say, how the blood goes round and round your body instead of going up and down. The doctors he was arguing with were arrogent because they would not listen to his theroy but there was one difference between the theroys of the other doctors and his, because he could prove himself right.

The next day a great agument took place, William was trieing to show the other doctors he was right.

'Your theroy is wrong. We have known the way the blood goes for centurys'

'but you're wrong it goes round and round and the heart pumps it round your body.'

'how can it stupid! You have two of everything so your body is devied into two so it goes up one side and down the same side, and while one side is going up the other side is down'

'That was the Greeks theroy but that was years ago. Time has proved them wrong I have cut open dead bodys of crimanals and I have traced the veins round and I found they all go round to the heart.'

This argument went on for hours. William even took them to his lab and he showed them how it worked, but they just said 'he was a crimanal so the body is wrong, we are right.

But in the end William proved himself right and his discovery was one of the greatest in history.

3. IMAGINATIVE TRANSFORMATIONS

Children naturally transform an experience via imagination–stories and poems may tumble out. I think we neglect the opportunities for an imaginative approach in science writing. See 'The Search for Air' (pp.10/1), 'The Unborn Child' (pp.11/2), 'Finding is Believing' (pp.24/5) and the following piece contributed by Jeff Shapland after the seminar.

BOY (3rd year)

Context:

This work was done by a third-year boy after some work on density and measurement of density in the lab. I suggested they could write it up in one of these ways:

a) as a letter from Archimedes to the King
b) as a letter from the King to Archimedes
c) as a newspaper report of the discovery and Archimedes' 'streak' through the village.

This boy's method and reasoning are quite sound even if it would be hard to put into practice. The 'eurks' etc. are his ideas.

Letter from Archimedes to the King

Dear King

I have found that your crown is not pure gold! I weighed it, and it weighed about 20 eurks*. I cut a bit of gold from the goldsmith's stone, which weighed 20 eurks. I then put the crown in my bath, and the water came up by 1 eurn*. A lump of pure gold was put into the bath, and the water came up by ¾ of an eurn. Also the crown has now gone rusty!

Your friend
Archimedes

P.S. The fee is 100 panus*.

* a panus is a greek coin
* an eurk is a measurement of weight
* an eurn is a measurement of length.

4. PROBLEM SOLVING AND DEVISING ONE'S OWN EXPERIMENTS

(A) ANDREW (1st year)

Context:

This is a report by Andrew, who changed his mind over what seeds need to germinate. In the class discussion he did not suggest that he would do his experiment this way. It seems that only by writing down his ideas did he organise his thinking and produce his own hypothesis in solving this problem.

Can seeds grow without some special parts?

First of all I drew some pictures in my book for water but I changed when I drew them with the skins off and in half to. Can seeds grow without special parts? I had to change my drawings as well when I had got the testubes I put some paper in the bottem then I labled the tubes. After that I took the certain pieces off I placed them in the appropite places and put some water in but when I removed the Hilum I left the skin on. The results prove that not all parts of a pea is needed.

MONDAY

A	Skin remmoved	two shoots 4cm and 3cm
B	radicle removed	no growth
C	skin	shrivled up
D	hilum removed	came out of skin radicle about 4cm
E	half	root curled about 4cm
F	plumule removed	radicle 5cm

WEDNESDAY

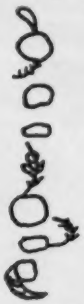
5 days later

A
B
C
D
E
F

The results prove that not all the parts of a pea are needed for germination

MONDAYS RESULTS ENLARGED

3 days later



This leads to more experiments for instance what is the skin for?

Andrew, and also Nigel (1 (B) above) both posed further problems in their reports. Writing should, I think, be seen as part of an on-going process. Modifications are always possible just as they are in a scientific investigation.

(B) *TWO GIRLS WORKING TOGETHER (1st year)*

Context:

A project: 'ourselves'–fingerprints. Showed them the technique–then they had to answer some oral questions–which caused them to create more questions/problems–they then worked on defining a problem and set themselves to tackle it.

They suggested they look at brothers and sisters to see if there were any family resemblances, and decided to limit their observations to the index finger of the right hand.

Teacher's instructions:

It would be useful to explain clearly what you have done, because, you realise, *I don't know what you have done.*

Report of the work on fingerprints

Background into fingerprints

Fingerprints are divided into four main groups (which are Arch, composite, loop and whorl). All through life fingerprints never change, not even if you scar yourself, because under each layer of skin has the same fingerprint so if you scar yourself it won't matter unless it is right down to the bone. In scotland yard there is up to 1,500,000 sets. An English man called Sir Edward Henry found a way of classifying fingerprints so they could be filed away, this system is used in most of the world today and was adopted in Scotland yard in 1901.

No body has the same fingerprints not even brothers and sisters although they may have the same group.

The question we asked

Then we asked the question do members of the same family e.g. brothers and sisters have the same group of finger prints.

Next we took all the brothers and sisters in the school and took their fingerprints to find if they had the same group.

How we came about getting the fingerprints

First of all we started with the little classes. We asked if any of the children has a brother or sister in the school, their quite a few so we took them three at a time. They went and got their brother or sister and we took their fingerprint. I put their finger on the pad then we pressed it hard, then we waited a while then pressed the finger on the paper the best paper we tryed was absorbent paper.

After a while we found this took too long so we started looking at the finger through a magnifying glass and we saw what they were straight away.

Fingerprints

1. All together there are seventy-six loops out of one-hundred and forty. That is 53%.
2. The least commonest is composite which only has three prints out of one-hundred and forty. Which is 2%.

The 'investigators' here explore various ways of organising the children who are the 'subjects' of their enquiry, and of taking fingerprints until they are able to do it in an efficient way. Their results astonished them and their last piece of work is a nice example of narrative report incorporating their findings.

Writing, like scientific thinking, has a tentativeness. It is on the way to something else. A good piece of transactional writing will only come when the writer knows what he's talking about and when there is a need to present it to someone else. Expressive writing allows time for new learning to develop into fuller understanding through experimentation, exploration and testing.

I would argue that the body of knowledge acquired in science is not the only consideration. The attitudes of enquiry and responsibility and an understanding of principles and processes are equally important. One involves the other. Further, that by valuing a child for himself and his modes of expression of himself we will make him more scientifically confident and aware. He will be more in control of his environment.

5. WORKSHEETS - MY CHANGING ATTITUDES TOWARDS THEM

by Jeff Shapland

In retrospect there are two reasons why we chose to use worksheets when Countesthorpe opened in 1970:

a) to enable us to operate mixed ability groups;
b) to enable students to work at their own pace.

Our example was undoubtedly the Nuffield Foundation Resources for Learning Project. I can't remember ever doubting that this was the best way to operate. I do so now for several reasons. As regards mixed ability teaching, I taught previously in a nine-form entry *banded* comprehensive, but we taught the same content to each band in the first year. So each band did, for instance, the rock salt experiment. So why do we now think that we have to write a worksheet for it just because the pupils are mixed instead of being in bands? If we feel that our approach to the different bands was different, and that this was a necessary part of the learning process, then it is logical that we should have several different varieties of worksheets on 'rock salt' for the different kids. Apart from the fact that this introduces a form of streaming into a mixed ability situation, we should never be able to cope with the production. I can see no reason why we couldn't carry on the 'rock salt type' activity with first years in mixed ability groups without worksheets for it.

What about students working at their own speed? Two ways of operating independent learning in mixed ability groups are: (i) a topic-by-topic approach—what Reid and Booth call short term independent learning—and (ii) long term independent learning, where pupils can move as rapidly as they wish. Reid and Booth conclude[1] that long term independent learning is less likely to be successful, except in highly structured courses (perhaps physics) and that it is rarely operated. So it would seem that many of the

hundreds of worksheets being produced at present are probably for use in short term (or medium term) independent learning, with all pupils say covering the topic of 'Energy', or 'Water', but with some doing it in greater depth. It would seem to me that in this situation it would not be impossible to operate without highly structured worksheets. Some written material, instructions, stimulating ideas, yes.

But there are other reasons why I became increasingly unhappy about the large-scale use of worksheets. First, because they only cater for the upper ability ranges. The average and below average are rarely stimulated by even the most attractively produced worksheet and many are less than that! Second because, although the use of worksheets frees the teacher from the central role of initiating all the activity, he is often replaced in the pupils' minds by the worksheet. I have seen kids as lost when the worksheets ran out as they used to be when the teacher didn't turn up. And, more important, the worksheets can come between the teacher and pupil, so although the teacher has more time to go to each group there is not a corresponding increase in pupil/teacher interaction. The student is often relating more to the worksheet. When I ask 'What exactly are you doing?' I often get the answer 'This bit here' (and they point to it).

Another worry is how far worksheets can encourage a scientific approach to problems, how far they can encourage a problem-solving approach. In particular, how can 'planning how to tackle a problem'[2] be encouraged if the worksheet goes on to state exactly what must be done to solve it?

And finally, but perhaps most important of all (after the science seminar at Wansfell), I am concerned at the way worksheets limit the students' use of language which could be so crucial in the learning process. If it is true that our first drafts of thinking start in the expressive and that the thrashing out of ideas in expressive language plays a crucial part in understanding, then it is clear that many of the worksheets I have written and many other people's do not (and possibly could not) make provision for this. Nuffield stated the case for pupils' records being personal back in 1966[3] but we forgot that in our enthusiasm to produce

worksheets.

So what now? Can we have a bonfire of all our worksheets, sell the offset litho and banda machines and dismiss our printers? I think not. We need printed materials and for some aspects of our work we may need worksheets. I would favour the following approach. For the first three years we should hope to do without closely structured worksheets on which pupils write. Small booklets of ideas and information may be required and other resources such as heat-sealed cards. (It is interesting that this is the way things have evolved—through feeling rather than rational thought—at Countesthorpe for Years 1-3.) In addition I would hope to see the use of written language encouraged positively—especially in imaginative situations. The problem with fourth and fifth years' mixed ability work, where some are working towards 'O' level/C.S.E. and some do the subject for interest's sake only, is more difficult. In chemistry I operate long term independent learning for this age range but I am only too well aware that those who gain most are the brightest students. They forge ahead, work enthusiastically and intelligently from the printed sheets, and get a good grasp of the subject *almost without any help from me*. And that is a cause for concern! Within a group of 20-25 fourth/fifth years there will be only about four groups of four working towards exams, and probably only six groups of four overall. I would like to explore the possibility of working with the groups, setting problems to be solved, advising on experiments, discussing results, and guiding them to background reading on a teacher/student basis without the worksheets coming in between.

Independent learning without worksheets—can it be done? If it can, I think the learning situation could be very much improved; the gulf between those who can operate with worksheets and those who can't would be narrowed, and everybody might be able to contribute to the raising and solving of the problems and we might get genuine mixed ability teaching. I intend to discuss it further with my colleagues with a view to trying it in the near future.

Notes

1. Reid D and Booth P, *Biology for the Individual* (series), Heinemann Educ. 1971

2. On the question of 'Planning how to tackle a problem' the *Nuffield Chemistry Introduction and Guide* has this to say (pp.4/5):

> *Our chief concern will be to encourage pupils to be scientific about a problem.* This means that they must have mental and manipulative skill in the exploration of a situation which, though familiar to us, is new to them. In all new situations one gropes and fumbles and is likely to make mistakes. This, however, is the exercise by which judgment develops. A pupil must have graded opportunities to be right or wrong, and he must be guided and encouraged to become better at finding out whether or not he is right. This is time-consuming at first but only time-wasting in the context of having to cover a traditional syllabus: properly organized, it brings considerable educational benefit later on. Our hardest task will be to extricate ourselves from 'the straitjacket of chronic success' and be willing to reconsider our methods. For example we have to learn to judge when to keep silent, leaving the pupil to puzzle the problem out by himself, and when to give encouragement and advice. That the pupil should see the point of experimental work is of the greatest importance. He must learn that chemicals, test-tubes, thermometers, and sources of heat and electrical energy are tools to which he should always turn to settle a point of curiosity or of speculation. He must learn that it is proper, not wrong, to have an opinion or an idea about something he observes, but he cannot begin to think he is scientific if he does not check whether his idea fits the observed experimental facts.
>
> If we are to develop science teaching along the lines of these proposals, the appropriate organization of laboratory work for classes of thirty or more will play a very important part. *Each experimental undertaking involves three EQUALLY important stages in which the pupil must take an active part*:
>
> a. *Planning how to tackle the problem.*
> b. Carrying out the experimental work.
> c. Discussing what deductions may, and may not, be made from the results.
>
> . . . *From the beginning they must be encouraged to think imaginatively about the problems confronting them, and to suggest further experiments and explanations.*

3. In Chapter 6 of the *Nuffield Chemistry Introduction and Guide* the authors raise two questions about writing: 'What is the purpose of keeping a record? Does the pertinence of this exercise change as the pupil gets

older?' They suggest the following major considerations (pp.105-107):

> The chief reason for making a pupil put something on to paper is to sharpen his understanding. What must be avoided is turning it into a chore and only the teacher can tell whether or not the written work is of value.
>
> The building up of a notebook is in most cases enjoyable and stimulating if it is *personal*; this can rarely be so if the material is dictated and made uniform throughout the class.
>
> . . . In the early part of the course, much that is done does not need permanent record. This not only applies to details of practical techniques, such as filtering and evaporating, but also to class discussions, and to many quick exploratory experiments. Young pupils want to be doing most of the time and must not be hampered by too much written work, which they often find difficult, and at which most of them are very slow. They should be encouraged to regard their notes as diaries in which they record, briefly and simply, the more important things that they do, and the significant speculations and conclusions that lead to and emerge from their experimentation. A good deal of guidance from the teacher will be essential at the beginning of the course. Methods of guidance—half-completed tables or sentences on the blackboard, skeleton notes, help in drawing labelled diagrams—are well known. However, as with all diaries, the individuality of the compiler will soon become apparent and some pupils will want to include samples of substances that they have made (sometimes at home), cuttings and illustrations from newspapers and periodicals, chromatograms, indicator colours, charts, and a host of other items. This should be encouraged but not insisted on. It is one way in which enthusiasm and interest will show themselves; these cannot be imposed but should be fostered.
>
> . . . Towards the end of the course we can say that the pupil's laboratory notebook should be a sort of journal of the progress of the work. It should contain more than a mere account of what operations he carried out and what results followed: when completed it should be a valuable account of the term's activity.

(Emphases in these extracts are Jeff Shapland's own.)

6. DO WORKSHEETS WORK?

by David Evans, Arthur Summerfield and Pat D'Arcy

We chose to study the worksheets that teachers had brought with them, because in spite of the drawbacks we thought that worksheets could help pupils to learn about science and how to approach and think about their environment scientifically for the following reasons:

- They can be useful for children working individually or in small groups and make it more possible for teachers to work effectively with mixed ability classes.
- They can replace spoken instructions to the whole class and free the teacher to spend more time moving round talking to small groups giving assistance when and where it is necessary.
- They make it easier for teachers to enable children to work at their own pace.
- Through the instructions and questions on a worksheet which follow an experiment through its various stages, the individual's attention can be focused on useful ways of conducting and interpreting the work in hand—i.e. pupils are given the opportunity to think, record, comment, and learn as they go along.
- Similarly, this demand for an immediate response to each step of an experiment can make for a more efficient learning situation than relying upon the child's capacity to write it all up clearly afterwards.
- If comments are noted on the worksheet itself in response to the teacher's written instructions or questions, the pupil is left with a record of his/her work which has a clear framework for future reference, but has not involved large amounts of writing.

- It is possible for a worksheet to include a useful combination of background information, experimental procedure and suggestions for further work.
- Structuring the activities of the class through worksheets can create a teaching/learning situation in which the problems of the individual child (both academic and social) can come to light without attracting the attention of the whole class.
- Worksheets can enable children to work independently in an active rather than a passive way.
- They can also encourage more peer group (c.f. teacher/class) discussions.

We accepted of course that as well as advantages worksheets also have some drawbacks—most obviously for pupils who have difficulty with reading and who therefore have to rely on other children to read the worksheets to them, or on trying to pick up what it is all about by watching the others, listening to them, and then guessing.

We agreed that there is a danger of overstructuring pupils' responses by too closed a set of instructions, although if a teacher is aware of this danger it can often be avoided by the deliberate use of open-ended questions.

Similarly there is the danger of the whole pattern of response becoming stereotyped if pupils come to regard filling in the sheet as the main task of every lesson.

In addition, this method of work presentation raises the following practical problems:

i) Even after considerable practice, worksheets are difficult and time consuming to write.

ii) A syllabus which relies mainly on worksheets has to have a very long life as it is confusing if the sheets are constantly changed. This need to retain the programme once it has been devised does have disadvantages: it may perpetutate actual mistakes which were missed before the sheet was run off—and it will hold up further modifications and

possibly prevent a department from developing its teaching techniques.

iii) Schools which do not possess sophisticated reprographic facilities are limited, sometimes frustratingly so, in the kind of worksheet presentation they can offer.

In this paper we have compiled a list of questions that we think could be asked about worksheets in general which were suggested to us by features of the particular worksheets that we had in front of us. We have tried to indicate briefly how our collection related to these questions. Other science teachers will no doubt find it useful to bear their own worksheets in mind as well.

1. How do worksheets approach, structure and make use of experimental work?
   a) By instructing?
   b) By encouraging interpretation through questioning? If so, through closed ended or open ended questioning?
   c) By encouraging the formulation of conclusions?
   d) By arousing curiosity and interest?
   e) By encouraging a variety of activities?
2. How much information do worksheets provide? Background information? Information on which to work? Informing after the event?
3. How far do worksheets act subsequently as useful reference material for the pupil?
4. How far does the nature of the worksheet depend on the nature of the topic?
5. How far do worksheets concentrate on tasks inside the laboratory and how far do they relate to the world outside?
6. Where do worksheets start—with the concrete or with the concept?

1. HOW DO WORKSHEETS APPROACH, STRUCTURE AND MAKE USE OF EXPERIMENTAL WORK?

a) Instruction

We found instructions on every worksheet that we looked at: What to do–What to write–Write–Explain–Give a name–Look–Copy–Collect/fetch–Stick–Read–Label–Put–See what hap-happens–Think about–Make a list–Draw–Add–Go and talk to another group . . . Many of the worksheets were strongly coloured by this regulative tone. At its best, a dialogue seemed to be set up between the writer and the reader as if the teacher were talking directly to the pupil:

> Set up the apparatus as shown.
> Pour in some oil up to the mark on the funnel–it doesn't matter where you put the mark.
> Now open the clip and watch the oil drip out.
> Decide for yourself how long to count the drops for; or decide to time, say, twenty drops.It's up to you.

At its worst, the total effect was a kind of relentless sergeant-major battery of instructions: Collect . . . Observe . . . Write . . .

b) Encouraging interpretation through questioning

Closed ended questions

By closed ended questions we meant questions that already had a specific answer clearly in mind, e.g. in 'An experiment using balloons':

> What gas is all around us in the room?
> Which gas used was lighter than air?

or

> How can you tell a vertebrate from an invertebrate?

This kind of question to 'guide' the reader into thinking (often sequentially) along the correct lines was common to many of the worksheets we looked at.

Open ended questions

Open ended questions which gave the reader scope for speculation were more difficult to find. Here are a few examples:

> You continuously produce tears to keep the front of your eyes moist. Why is this necessary? You may think of several ideas.
>
> Do some tests on your samples. Decide what questions to ask and how to report your answers.
>
> Explain how you could tell if the monster in the biology pond is an animal or a plant.

To some extent all these questions are limited by their frame of reference but in every case they allow for more than one answer and seem to be inviting the reader to think *round* the question rather than in a straight line from question to answer. We would be interested to receive further examples of such questions, partly because they were more difficult to find than the closed ended variety and partly because the science teachers at our weekend all agreed that speculation as well as correct deduction was an important aspect of scientific thought.

c) Encouraging the formulation of conclusions

Several worksheets which were so structured that they moved through a series of closed ended questions completed the sequence with a question which encouraged the reader/writer to draw them all together to a logical conclusion, e.g. in a worksheet on pressure:

> Describe how the indentations in the clay differed . . . for 1, 2, 3, 4 cubes. No matter how many cubes were used the force pressing down each time was the same. Why? What then caused the different indentations in the plasticene?

or

> Which job made the blade bend most?
> Which job made the blade bend least?
> Which job took the biggest force?
> Which job took the smallest force?

* * * * * * * * * * * * * * *

Complete the following sentence by filling in the blanks:

When the blade bends most we have the _____ force.
When the blade bends least we have the _____ force.

An important aspect of this kind of 'conclusion' seems to be its capacity to generalise, i.e. to move from the specific 'experiment' to a summing up of what has been done which may then be linked with further experiments.

d) Arousing curiosity and interest

Some of the worksheets that we looked at seemed to aim at arousing the pupil's curiosity and interest through their illustrations—for example, a large coffin drawn on the first page of a booklet on acids under the question 'Do you think that tasting is usually a good way of testing things in the lab?'

Another booklet had the words—

MYSTERIOUS GASES

across the cover and in the introductory paragraph over the page:

> Solids and liquids are things we can see and touch and sometimes smell, but gases are mysterious. Most gases have no colour so we cannot tell if they are there or not. Some gases we breathe every day but others are so poisonous that just one sniff could kill us. Some gases start fires, other gases stop them. So gases are very strange substances. In this section you are going to make some gases to find out how to tell one gas from another.

The invitation to the pupil to experiment for himself is probably the most common method of rousing his interest and curiosity in science. Here is another example:

> Spot the metal
>
> Mystery substance 'X' is a metal compound. Try to find out which metal is present in substance X.

A less common way of stimulating an interest in the work that is to be undertaken is by inviting the children to discuss the

possibilities together in small groups. ('Other groups may have got different results from you–go and find out').

e) Encouraging a variety of activities

How far do worksheets which are themselves a form of written communication rely on writing in return, and how far do they specifically suggest a wider range of activities? If we look back to our list of instructions we shall see that between them they require thinking, talking, reading, doing things, writing and drawing. However, these activities do not occur with the same frequency in all the sheets. We had to look very hard to find an explicit referance to talk–whereas instructions to write were common: what to write, copy, label, make a list . . . Expressions like 'explain' and 'give a name' were very common–where implicitly writing rather than talking seemed to be the desired activity.

All worksheets contained instructions to their readers about 'what to do':

> You are now going to begin to find out exactly what pressure is.
> You will need two small square pieces of hardboard, about 250g of plasticene, a few 1cm wooden cubes and a 1kg mass.
> Work the plasticene until it is soft. Then press it between the two pieces of hardboard until you have a disc about 1.5cm thick . . .

So doing and writing, especially writing about what has been done, are both activities commonly suggested on worksheets.

By their nature, instructions tend to be directive rather than suggestive, but there were also some questions on some of the worksheets which seemed to be aimed at encouraging children to think. One of the problems with such questions (which hopefully encourage thought but don't ask for a written response) is the difficulty of ensuring that children bother to stop and do the thinking. Both the science teachers engaged in this study acknowledged the danger of worksheets inducing a 'form-filling' approach in which the pupil's aim was to complete the sheet as quickly as possible in order to move on to the next one. When such an attitude develops, the interaction between the pupil and

the environment that the worksheet is supposed to be helping him to study is minimal. The worksheet may even prevent him from any genuine observation and interpretation of phenomena because his attention is more fixed on filling in the blanks than on what is actually happening.

Other activities to which pupils were directed are reflected in the following quotations:

> Here is a sort of quiz . . . You may have to look up some of the answers in books . . .
> A crossword about . . .
> You can listen to some of the extracts from this book on tape . . .
> You could do a project on . . .
> Have a close look at . . .
> Write a story about . . .
> The Oil Game—a minimum of eight people are required for this game . . .
> Draw a diagram . . .

But the overriding impression from the worksheets is that the most common framework for what goes on in the lab. is largely 'what to do' and 'what to write'.

2. HOW FAR DO WORKSHEETS PROVIDE INFORMATION?

In addition to directing children through experiments and requiring them to write about what they have done, worksheets can also provide information of various kinds. Sometimes teachers produce booklets rather than straight 'worksheets' with fairly extensive background information about the topic to be studied. In the 'Fuels' booklet for instance (twelve A4 pages stapled together) two extracts from George Orwell's book *The Road to Wigan Pier* were included in the section on coal; so were a potted history of different kinds of coal, an extensively labelled photograph of a Rotary Drilling Rig, a short description of 'Improving Oil by Cracking', along with diagrams of two different molecular structures for petrol and heavy oils, two photocopied newspaper reports about pollution and an article from the *New Scientist* about 'Solar Power in the Third World'.

The science teachers in the seminar were generally agreed that referring children, particularly in the 11-13 age range, to textbooks which incorporated more extensive information was often difficult and not very satisfactory. Even in the older age groups one of the drawbacks about textbooks is that the knowledge which they contain between their covers is already so familiar to the writer that his 'distillation' of what he knows is too shaped and polished for learners to find any 'way in' for themselves. To change the metaphor—brief snippets of information incorporated into worksheets and related directly to experimental work may be more easily assimilated by the inexperienced reader than the equivalent to a seven-course meal which has already been predigested by someone else!

Other kinds of information which seem to be regarded by science teachers as sufficiently useful to put into their own writings for students include information on which to act directly, e.g.

> Your first problem is to make the copper part of the copper ore dissolve. It will not dissolve in water—so you are going to use dilute sulphuric acid. N.B. Sulphuric acid can burn you, your clothes, and the bench if spilt.

and also information 'after the event', usually to tell students the technical name for what they have just been doing, e.g.

> The process you have just described is called evaporating.

or

> You have just *classified* some living things.

Sometimes, too, information has to be given about an unfamiliar piece of apparatus and what to do with it, e.g.

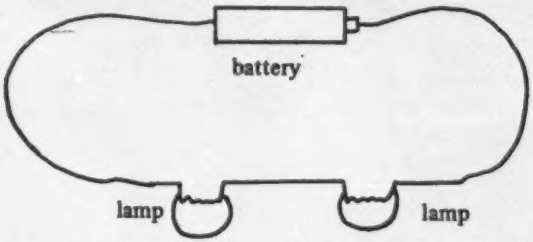
> The piece of apparatus in front of you is a newtonmeter, it can be used to measure the size of forces in newtons. So a force of eight newtons would be 8N.

Sometimes the information given refers the student to further information elsewhere, e.g.

Filtration is often a slow process. It can be speeded up by using a *filter pump*. The apparatus for this is set up in the laboratory. Activity 91 gives an explanatory diagram.

Sometimes of course the necessary information for setting up an experiment is conveyed most clearly and succinctly by means of a diagram, e.g.

Begin with a circuit containing one battery as before, but with two lamps instead of one like this:



One of the questions we asked ourselves was to do with the most effective means of conveying information clearly on a worksheet. Often a diagram may be more effective than a string of words, so may the use of graphs and charts—although in the collection of sheets and booklets that we had for reference, words were more commonly used than any other method.

3. HOW FAR DO WORKSHEETS ACT AS USEFUL REFERENCE MATERIAL?

From the worksheets available to us, those which seemed to provide the most useful reference material for later were those on which the students actually wrote—within the framework of questions and instructions that the teacher had planned, in order to give the pupil the maximum opportunity to gain a clear insight into the significance of what he was being asked to do, e.g.

How atoms are arranged in things

A wall might be made of bricks. We can easily see the way the bricks are arranged. Do you think the way the bricks are arranged affects

the strength of the wall? If so, why?

(Space of three lines left)

Think of a piece of iron or a piece of sulphur. These are not made of bricks but of atoms. We can ask a similar question, 'How are the atoms arranged in iron and sulphur?' *but* we cannot just look and see the atoms.

Perhaps we can make some guesses by thinking about the properties of things. Iron is tough and strong, you can bend a nail and it does not break. Sulphur is brittle, it shatters if you hit it. In which do you think the atoms are held most strongly, iron or sulphur?

(Space of one line left)

Now think of atoms in a liquid or a gas or a solid. What do you think is the difference between the way the atoms are arranged in each of them?

(Space of three lines left)

The answers that the pupil writes down (hopefully) are closely related to the questions he has been asked and when he comes to go over the work this not only reminds him of the context for the experiments that he did, it should also remind him of the logical connections between one step of the experiment and the next. Where answers or comments are written in a separate file or exercise book it is sometimes difficult (for the teacher as well as for the pupil) to relate them back so clearly to the work done in the lab.

On the other hand, writing on the actual worksheet involves difficulties of spacing—how much to leave or how little. Usually fairly brief answers are required (most of the questions are of the closed ended kind) so that the pupil may in a sense become conditioned to the teacher doing much of his thinking for him while he just dots the i's and crosses the t's.

There is also the difficulty of persuading the pupil that each worksheet is worth filing away once he has completed the activities it suggests. It is popularly assumed that one of the chief advantages that written language has over spoken is its availability for future reference. Children often advance this as a reason

for writing themselves, even though the actuality of close and detailed reference back to completed work is sometimes more fictitious than factual. In children's eyes work already done is work that is finished with—until the fear of doing badly in 'the exam' persuades some of them differently. Ultimately, there is still the question of how much of what is learnt will be retained.

4. HOW FAR DOES THE NATURE OF THE WORKSHEET DEPEND ON THE NATURE OF THE TOPIC?

It was clear from our sample of worksheets that the presentation varied according to function. For instance, if the teacher's main objective was to enable his pupils to grasp a scientific concept, the worksheet was often carefully structured in exactly the way that the one we have just quoted from was structured, moving in a step by step way from what the reader can be expected to know already to the introduction and assimilation of new knowledge. Many of the worksheets used such a question/answer method to move towards the formation of a concept (classification, pressure, magnetism, molecular structure).And in all these instances the worksheet was 'closed' in the sense that it was structured towards a clearly defined outcome which the teacher had in mind from the start.

In other instances the main function of the worksheet was to encourage pupils to observe phenomena at first hand, and in some cases to produce for themselves the materials for their study—crystals, for example, or bacteria. In this kind of worksheet fairly directive instructions were given (often with the aid of diagrams) followed by questions which gave the pupils 'clues' about what they should be looking for, e.g.

> There are a number of solutions (labelled 'for growing crystals'). Choose one—copper sulphate is a good one to start with. Then follow the diagrams. [Diagrams given] As the liquid cools, small crystals should form. Watch them grow. (If they do not form, heat the solution a bit more and try again.)

Then:

Have all the crystals *curved* or *straight* sides? Are all the crystals of *one sort*? e.g. a *similar* shape or very different shapes?

and so on. Sometimes, if the phenomena to be observed were as easily found outside the lab. as in, the suggestions for observing them were more open ended, e.g.

Write about your own animals at home.

or

Who has the best eyesight in your family? How can you tell?

But mostly, even when a new concept was not involved, the suggestions for what should be done were fairly clearly spelt out.

In some worksheets an important feature of the activity to which the sheet is related is the use of new equipment or new substances (v. Nigel, pp.21/2: 'My project worked very well and I'm pleased because . . . I used some new aquipment which I've never herd of let alone worked with'). In such instances the language is concerned with operational details and exhortations to proceed carefully! e.g.

Finding out about Electric Circuits

You will need:	A Circuit Board	Some spring connectors
	Three batteries	Some lamp holder connectors
	A box of lamps	2 plug/crocodile clip leads

You can use these to investigate the behaviour of simple electric circuits. Look at Figure 2 in Activities Book 5. This shows you how to use the board. The batteries fit into the clips on one side. *Do not strain the clips–the batteries must fit tightly*. The lamps fit into lamp-holder connectors which fit between the short vertical rods. *Do not screw the lamps in too tightly–this will strain the lamp holders*. The lamp arrangements are connected to the batteries by the two plug/croc leads. For more involved circuits you may need ordinary spring connectors as well.

Finally, if the topic is broad enough (like fuels or detergents) the teacher may include a fair amount of background information of relevant historical or geographical interest as well as directions for experiments to analyse the nature and properties

of the substance. Which really leads us on to our next question about breadth of focus.

5. HOW FAR DO WORKSHEETS CONCENTRATE ON TASKS INSIDE THE LABORATORY AND HOW FAR DO THEY RELATE TO THE WORLD OUTSIDE?

We asked this question because we thought that some children might be helped to see the relevance of what they were doing in the laboratory to 'applied science' if explicit connections were made between their experiments and the practical application of such work in their everyday lives.

Background information about the substances or processes that are used in the lab. is one way of making such direct links. Thus in one worksheet on fuels, as we have already noted, George Orwell's visit to a coal mine is quoted and so are newspaper cuttings about oil pollution. In this way students are encouraged to think about the problems caused by some of these fuels in our society today.

All the science teachers at the seminar had agreed in discussion that it is very important to relate work in science to society outside the laboratory. At the end of this particular booklet students were invited to conduct their own survey into how various fuels were used locally—and to set up a campaign (starting in the school) for more economic ways of using what fuels we have. But no other worksheet in our collection made a direct connection of this kind. More often the sort of extended work that was suggested involved further reading.

Several worksheets made a series of 'links in passing' to relate the concepts that were under consideration to knowledge drawn from children's own experience, e.g.

> What is meant by the word pressure? In what circumstances have you heard it used?
>
> Look at Activity 48 (Book4). When weather forecasters talk about pressure what is it they are discussing the pressure of? Why is it

necessary for forecasters to know about this pressure? How does it affect the weather?

and in the next section of the same sheet, previous work with gas under pressure in cylinders is related to air pressure in bicycle tyres. In this instance the learner is being encouraged by the teacher to move back and forth between the *new* situation that he is observing in the lab. and others with which he is already familiar, interpreting them alongside each other.

Similarly in a worksheet on crystals, attention was drawn to the patterns of zinc crystals on galvanised buckets and dustbins and tin crystals on cans of fruit, as well as to the patterns of crystals that had been grown in special solutions in the lab. And in a booklet on acids and alkalis there were photographs of a bottle of Britvic grapefruit juice and an 'Eno sparkling antacid fruit salt' label as well as diagrams of experiments with litmus solution and U.I. paper. Those of us studying worksheets agreed that this kind of back and forth movement from the enclosed world of special apparatus and rows of bottles to the world outside was helpful both in gaining and maintaining the pupils' interest, and in focussing their attention on the practical application of the experimental activities that were specially set up for them.

We were also agreed that lab. experiments with special apparatus—circuit boards, microscopes, condensers and so forth—should not be discounted just because they were not naturally observed phenomena. Often they could provide the necessary insights about abstract concepts in physics and chemistry more efficiently and economically than references to more 'real' examples could do. One teacher pointed out for instance that it is both simpler and more practical to introduce the concept of electrical circuits by using circuit boards than by stripping down the engine of a car.

6. WHERE DO WORKSHEETS START— WITH THE CONCRETE OR WITH THE CONCEPT?

We asked this question because when we looked at the work-

sheets in front of us it seemed that there was a tendency for the teacher, who was already in possession of the overall pattern of what he was intending to present, to pass it on rather too quickly in an abstract, 'distilled' form to readers who might often have only the slenderest of contexts inside their own heads into which such complex information could be fitted.

A worksheet on elements and compounds began:

> What to write:
>
> The world is made up of 92 different elements like hydrogen, oxygen, sulphur etc. What can you say about all the particles that make up one of these elements such as copper?

Another worksheet about measuring forces began:

> This piece of apparatus in front of you is a newtonmeter; it can be used to measure the size of forces in newtons. We use a capital N to mean newtons. So a force of eight newtons would be 8N.

On this sheet the pupil was then instructed to use the apparatus to measure some forces for himself:

> In front of you are some objects on a tray with some string.
> *Lift each object off the bench using the newtonmeter.*
> Write down the name of the object and the size of the force needed to lift it.
> Put your answers in the chart below.
> *Measure the force you can pull with the little finger of your left hand.*

So having been given the concept that force can be measured, the student is asked to try it out.

The 'Elements and Compounds' worksheet is more confusing in the way it moves from concept to concrete–although it may be that the teacher is relying on some prior knowledge of his pupils that we don't know about. After the initial statement and question that we quoted above comes the following:

> There are literally thousands of different substances in the world and yet there are only 92 elements. Which of the following statements,

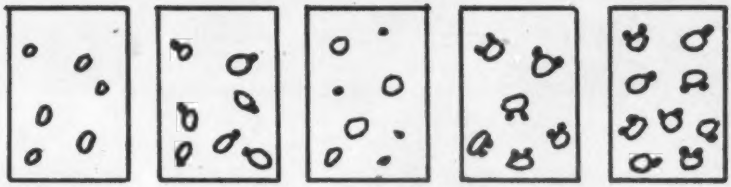
A, B or C, completes this sentence: 'The 92 elements in the world can form thousands of different substances because . . .'

a) there are thousands of different types of atom.
b) the atoms of many different elements join together in different ways to form compounds.
c) the atoms of the different elements are all jumbled up in different ways in the world.

The worksheet continues:

Here are some diagrams showing the particles making up different substances. Compare them with the diagrams you will find on the wall chart and then try to answer the questions.

A B C D E



Write down the letters of all the ones which are or represent:

i) pure elements
ii) mixtures
iii) a pure compound
iv) a mixture of elements
v) a mixture of compounds

It seemed to us that unless a child already knew very clearly what the differences were between elements and compounds in a fair amount of detail, this kind of presentation would confuse rather than help him.

Here, by contrast, is the beginning of a worksheet called 'Finding out about Electric Circuits', which begins with the concrete and then asks the student to make his own deductions from what he observes:

You will need:

A Circuit Board	Some spring connectors
Three batteries	Some lampholder connectors
A box of lamps	2 plug/crocodile clip leads

Set up the circuit shown in figure 2 with one battery and one lamp. The lamp should light.

If it does not light, in fact if at any time a circuit that you have set up does not work, check which part is faulty using the test apparatus.

When the circuit is working, try 'breaking the circuit', i.e. disconnecting the parts at any point in the circuit you like. What always happens?

What then do you deduce that must be true about any electrical circuit if it is to work?

In our collection, worksheets that started like this were less common than those which told children what they were going to test or to find out *before* they actually did it. This may have been chance, but it may reflect a more common approach to the presentation of work in science lessons. What is really at issue, of course, is the by now familiar educational question—do children learn more effectively by being told or by finding out? In this connection science teachers must decide whether it is more useful for their pupils to be given concepts as a framework of reference for subsequent experimental work or whether they are likely likely to gain a clearer insight into concepts by arriving at them through experimentation. Judging from our worksheets, most teachers seem to opt for concepts first.

7. ALTERNATIVES TO THE 'EXAMINER' AUDIENCE

by John Cockings, Margaret Tucker and Harold Smith

We took as our starting point the sense of audience which influences the writer. We listed some of the possible audiences which the Writing Research Unit had found operating in schools. They were:

The Self (writer as his own audience)
Child to Trusted Adult
Pupil to Teacher as Partner in Dialogue
Pupil to Teacher in Apprentice-Master Relationship
Pupil to Teacher seen as Examiner
Various Peer-group Audiences
Writer to 'his Public'.

Much of the writing we had seen was addressed to a teacher seen as examiner, and we were concerned by the narrow range of kinds of writing this had induced in science lessons, because we felt that the concentration on satisfying an examiner audience had led to formalised and unthinking writing; that such a concentration could have acted in a way that actively inhibited thought.

So we set out to examine the possibilities of using other audiences, and particularly other teacher audiences: teacher as partner in dialogue (a dialogue which we considered could contribute to learning rather than test it), and also the special relationship, now usually confined to just a few sixth-formers, where teacher and pupil, via their interest in the subject, roughly approximate to master and apprentice.

However, we foresaw considerable difficulties in changing the teacher-pupil relationship in the short term; the pupil, after all, comes to the teacher with already formed expectations of what this teacher wants of him, and also with already formed ideas about what writing is for. If the survey taken by the Writing Research Unit still holds good, both sets of expectations will very likely be limited in scope, and probably not recognised or be capable of verbalisation by the pupil. So merely saying 'Today I am not to be seen as an examiner' may mean little. The tasks we, as teachers, have set, the ways we have received them, the importance we have invested in marks and grades—all these will make it very difficult for the pupil to envisage a teacher audience in any other way. We are not saying that it is impossible—clearly a learning dialogue does take place in writing between some pupils and some teachers in some situations; rather are we saying that it may well be easier for the pupils to envisage different teacher audiences if they have the opportunity to write for a variety of perhaps non-teacher audiences, hence breaking their expectation that writing serves only one purpose and operates in only one situation (the assessment one). So what we needed to do was to make a collection of situations which in themselves would provide valid opportunities for the learning of science, but which would, at the same time, provide different audiences for the writing. The rationale would be on the lines of:

- Pupil operates in new situation.
- He finds out the requirements and limitations of that situation.
- He assesses the needs of his audience.
- He tries to satisfy those needs.
- With experience he builds up an ability to assess and satisfy the needs of different audiences.
- He develops different strategies to meet different situations.
- He recognises the possibilities of writing as an aid to thought and as a vehicle for communication in situations other than the examination one.
- His understanding of science increases, because he cannot satisfy all the needs that he wants to satisfy unless the understanding does increase.

We did not expect to find 'new' situations, merely to decide on those which would satisfy the criteria we considered important.

The situations might be such that they could only be used for a short time or be of a much more permanent nature, but they had to be useful in themselves as well as being part of a change of atmosphere that would lead to wider expectations. So what we were about was attempting to change an atmosphere, setting up a different picture of 'what happens in Mr X's class'.

In coming towards the situations we tried to bear in mind four factors which we felt important: the marking load of the teacher, the effect of the consideration of writing on how we saw other learning activities, the effect of compulsion to write, and the possibility of using assessors other than the teacher in the hope that the pupil could move more closely towards self-criticism.

a) The marking load Many teachers face a marking load which considerably reduces the time and energy available for preparation and thinking. We would hope to find ways in which pupils could make use of writing as an aid to learning which would not increase the marking load, and, preferably, reduce it.

b) Effects on other learning activities We recognised that there was a close link between the kinds of writing which predominate and the sort of organisation that operates through class teaching and a view of the teacher which sees him as custodian of knowledge and arbiter of correctness. That view might change to teacher being seen as something nearer a facilitator, a provider of opportunities for enquiry and learning, a suggester of new areas and methods of investigation. (The reader of this pamphlet may be interested to compare our attitudes here with those of Jeff Shapland, quoted in Paper 5.)

c) Effect of compulsion We felt that one effect of compulsion was to make it more likely that the situation would be that of examination. We do not want to suggest a wholesale removal of the element of compulsion, but we felt that some of the possibilities were only likely to arise when the pupil chose to write, or chose the way he wrote, or chose his audience. The chances of his offering tentative hypotheses, for instance, would be much improved if his audience were one to whom he felt he could safely offer such hypotheses.

d) Assessors other than teacher We felt that assessment by the group (sometimes including teacher, sometimes not) had much to offer in that it broke the attitude that the teacher was the only person qualified to assess–and might lead to self-assessment or self-evaluation which would almost certainly have a beneficial effect on the pupil's level of understanding. A result of this would be for instance that there would be no point in the pupil covering up his own misunderstandings–and he might come to recognise much more clearly that he had such misunderstandings and where they lay.

SITUATIONS (1) Communicating with co-workers

The first group of situations we considered were thought of as putting the pupil in the role of expert–and ranged from drawing on already existing expertise, as in the case of the child already extremely knowledgeable about market gardening, bird-watching or whatever, to situations where the child developed a new expertise or a new piece of knowledge which the others didn't have, as in group work with groups doing different things and writing for other groups, or where pupils plan their own enquiries and then write for other pupils or for a teacher who would really need to be told what had been done and found out–genuine communication, informing those who need and want to be informed rather than informing the already informed. We were impressed by the example of Nigel's C.S.E. project (quoted on pp.21/2) where the individual enquiry had led to speculation and forward planning–moving towards a concern for hypothesis and experimental design which would have been much less likely to occur in a more 'teacher controlled' situation. Individual enquiry could also lead to useful joint work; for example, we were impressed by examples of communal conclusions–particularly in a situation in which pupils were asked to 'find their own patterns' and consider the validity of individual suggestions. For example we heard of a class discussion in which all members made suggestions which were put on the board, argued about, and agreements or disagreements checked up on. It was a slow process, but, with the teacher keeping very much in the background, it was possible for the pupils to take their thinking much further as a result of their being pushed into justifying

their arguments in the face of questioning and criticism from their classmates.

SITUATIONS (2) Some public audiences

Still with a concern to 'break' the examiner audience expectation, there was throughout our discussions a concern with 'who makes the choices?' and we felt that this could extend from pupil planning his own experiment and group discussion of findings to pupils deciding the sort of effect they wanted to create through their writings–particularly where such writings were intended for a wider public with whom they couldn't draw on shared contexts and shared experiences.

The 'writing for the public' possibilities started from wall display or the production of folders/'books'–diagrammatic, written, photographic–which would be essentially for a small 'public'; through the wall newspaper, notice-board, regular school magazine, for which the audience would be wider; to taking advantage of school events–the 'open day', the visit from the primary schools of next year's intake–by presenting in the area of 'the sort of thing we do in science here'. The primary school children as audience seemed to present particularly wide possibilities–leaflets, guides to the lab. etc. when they visited, displays in the separate primary schools etc.

SITUATIONS (3) Writer as his own audience

As well as using wider audiences we felt there was considerable value in the narrowest audience of all–the self. The private record, science diary–containing what had been done and probably reactions to it–might also lead to the sort of self-assessment we considered valuable. To operate well, such a record would need to be private–it could be shown to a teacher but the teacher would have no *right* to see it; entries would be decided upon by the pupil and be as regular or irregular as he wanted. At first time would have to be allotted–a few minutes per lesson–to remove the 'unusual' feeling, but later those that wished to make entries could find their own time.

SITUATIONS (4) Non-examiner teacher audiences

We have looked so far mainly at audiences other than the teacher. But bearing in mind that one of our aims is to reach pupil-teacher dialogue in writing we must also consider the different ways teachers may be seen according to the 'social' relationships between teacher and pupil. Two categories seemed most relevant here: 'child to trusted adult' and 'apprentice to master'. We felt that the most fruitful possibilities for these were where pupils and teacher had a shared experience which might include the 'non-science', perhaps 'affective' part of the experience which would be *shared* in an atmosphere of trust and mutual respect.

Summary of situations–and what they would allow for

1. Groups writing for other groups.
2. Whole class discussing results and developing theory. Joint report.
3. Individual using already developed expertise.
4. Display e.g. for Junior School pupils) Possibility of pupils
   Open evenings) deciding what image
   General public) they want to project.
5. School or classroom newspaper/broadsheet.
6. Science log-book or diary.
7. The project or personal enquiry.
8. Pupil planning his own work.
9. Shared experiences that might be 'whole' experiences rather than purely 'scientific' experiences.

SITUATIONS		1	2	3	4	5	6	7	8	9
Would allow for:										
Choice					•	•	•		•	
Informing	)	•	•	•	•	•			•	
Persuading	) Functions		•		•	•				
Speculating	)		•	•			•	•	•	•
The expressive	)	•		•	•	•	•	•		•
Teacher/pupil dialogue in writing	)						•	•	•	•
Self as audience	) Sense of				•	•	•		•	
Apprentice/master	) Audience							•	•	
Trusted adult	)							•		•

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Our final task was to attempt to relate the situations outlined to the content of the science programme, and this we attempted to do by taking the Nuffield Combined Science course as a starting point.

We considered one particular section of the course–that in which the pupil is asked to survey his peers (Comb. Sci., Sect. 1, Act. Bk.1, 65) and tried to see which of our situations would be valuable in that enquiry.

Section of course: 'Surveys of my year'

- Possibilities: sizes of shoes, waists, heads, heights, weights, birthday months, favourite football teams, colours of eyes, hair, length of hair etc.
- Work could be individual or in small groups, with reports for each other (duplicated?) Class discussion leading to class findings. Many possibilities for display or for personal project leading to theories of relationship between height and weight, waist size and weight, leg length and height etc.
- The use of a variety of reporting techniques–formal written report, more personal written report, inclusion of hypothesis, use of graphical and diagrammatic forms, use of mathematical language.
- Variation of content and style for different audiences and different interests.
- Possibility of coming towards understanding of some of the techniques of statisticians and advertisers.
- The different language needs for audiences who will question size of sample etc.

We had not the time, of course, to attempt to repeat this sort of exercise for all sections of the Combined Science programme, but our impression is that many of its topics are capable of being usefully treated in the ways we have outlined.